7.0. ADDITIONAL CONSIDERATIONS

Squires et al. (1996) designed a monitoring program in support of the St. Lucie Watershed Assessment Plan. A number of recommendations regarding the application of HSPF were made and are recalled in the following text.

7.1 Effect of Simulation Time-step on Well-Mixed Modeling Approach

The interaction between the segmentation of the watershed and the simulation time step has important water quality simulation implications. The hydraulic routing algorithms work best when the mean flow 'travel time' through a reach is close to the simulation time-step. Realistically, stream flows will vary over time by an order of magnitude or more during the year and the physical segmentation of the basin may dictate grossly disparate reaches. Choosing a suitable time-step is an exercise requiring some judgement to best reflect the flow conditions which will occur most of the time for the majority of the reaches such that the overall potential for error is minimized. While exact influences on water quality modeling results cannot be estimated until the modeling is actually performed and results compared with available field data, several scenarios illustrating potential difficulties can be postulated.

Consider the following scenario: Assume that a simple system of upland subbasins contributing to a stream is being simulated. Due to the density of drainage features, stream reaches are developed which have a typical 'travel time' of only a few minutes each during a normal storm event. However, the modeling time-step has been chosen as one hour. Assuming that the model-predicted upland loadings are fairly accurate, a difficulty with stream concentrations can occur. Assume that the greatest loading occurs in the furthest upstream subbasin of the system. During the event, runoff is generated and heavy loads enter the upstream reach. In reality, this loading would rapidly move downstream as a concentrated slug through a series of the short travel time reaches during the simulated hour-long time step. In the model, only some of the material would be discharged from the upstream reach to the next downstream reach during the first hourly time step, to be diluted and further discharged to the next reach, and so on through the system. More of the concentrated material would be routed during the subsequent time-step, with the result that a process which should occur rapidly is greatly slowed down. The implication is that the time step chosen in this case will drastically reduce the predicted peak concentrations downstream and generate a much flatter discharge curve for entrained materials over a longer period of time. The simulated longer retention time of the pollutant materials in the system can also lead to difficulties with over-prediction of chemical and biological activity. Under this scenario, the model-predicted total load from an event may still be fairly good but the concentration information may not be meaningful.

Another scenario looking at the opposite problem can also be examined. When reach 'travel times' are much greater than the simulation time-step, another modeling anomaly results from the method of calculation. Assume again a loading introduced in the most upstream reach. The reach routing

calculation will duly mix and discharge some of the pollutant downstream through the entire system during a single time step. The result is that material that may in reality take many hours or days to travel the length of the system will begin to unrealistically appear at the system outlet almost immediately due to the time-step mismatch. Again, the model will show a flattened and skewed discharge curve for entrained materials. In this case, concentrations downstream may be over-predicted at certain points in time due to the storage routing interaction with the time step and the effects of chemical and biological activity may be under-predicted due to material moving through the system too quickly. Again with this scenario, the model-predicted total load may be fairly good but the concentration and timing of materials discharged could be way off.

Additional difficulties will arise when subbasins and reaches of greatly different sizes and 'travel times' are modeled. In such cases, parameter adjustments made to improve the performance of certain elements of the system may have entirely unintended effects on same-type elements which differ grossly in size.

An often repeated mantra is that the key to successful modeling is to 'get the hydrology right'. While this is an essential and necessary first step, it does not automatically follow that water quality modeling results will then also be 'right' with some parameter adjustment and model calibration. In the above examples, with either skew on time-step and system segmentation, a good hydrologist will most likely be able to get very good representative hydrologic performance from the model. Yet, as illustrated, the water quality results could be very dissimilar and differently skewed from the performance of the real system. The best answer to the dilemmas posed above arises in carefully delineating subbasins and reaches which are fairly uniform in size and performance and choosing an appropriate simulation time step to match. The problem with this is that the watershed will often not lend itself to such neat dissection and modeling data inputs will not match the desired time step. The art of modeling lies in carefully choosing compromises so that the final product reflects the system under study and most 'correctly' discriminates the phenomenon of greatest interest.

HSPF is currently undergoing an upgrade whereby the output from HSPF will be able to be read by a stand alone one-dimensional unsteady flow model (FEQ) via HEC-DSS. The models will have to be run iteratively until equilibrium is established. The primary canal system of the SLEW will be modeled by FEQ and not HSPF. Since FEQ does not have water quality transport modeling capability, a very simple approach to estimating pollutant loads at the major structures will be used. Unit pollutographs from HSPF will be manually aggregated and adjusted to account for the complex processes that occur (or are assumed to not occur) in the primary canal up to the major structure.

Coupling of the HSPF and FEQ models could be done in several ways. FEQ-generated time series outputs of flows from each reach could be stored, possibly aggregated to a coarser time step. An HSPF reach-only run could then use those time series, along with pre-generated upland runoff loadings, to perform the water quality calculations. HSPF and FEQ would alternate execution on a fairly close interval. The key concern would be to determine how frequently HSPF should be run

to still produce reasonable water quality results. A preprocessor routine could reconstruct the HSPF input for the reach run to accommodate changes in routing, as predicted by flow reversals, etc., as needed.

7.2. Recommendations for Water Quality Model Capability Upgrades

As with any model, the water quality modeling capabilities of HSPF would benefit from a number of improvements to the simulation algorithms or additions to the model's features. Some of the existing limitations are artifacts of the model's development history and attempts to use the model for purposes beyond the original intent.

The background of the HSPF model was the development of several agricultural runoff models. Modeling assumptions made for the earlier efforts were carried over through different incarnations of the agricultural models and still exist in HSPF. The basic model was designed and tested for agricultural field runoff from fields 5 - 40 acres in size using a simulation time step of 5 or 15 minutes. Many subsequent applications of HSPF have been made at a watershed - subbasin scale and have often used an hourly or daily time-step.

Water quality modeling with HSPF can be complicated by issues related to how the model calculations are performed. Some of the simulation routines are dimensionally inconsistent but can be made to produce reasonable results through calibration adjustments. Many of the model algorithms are highly dependent on the chosen simulation time-step, potentially requiring changes in parameter values for use with a different simulation time-step. In some cases, water quality routines can be invoked at different time-step intervals than the associated hydrologic routines.

The comments below mainly address the more detailed simulation processes such as the subsurface soil nutrient capabilities of the PERLND module. RCHRES simulation capabilities are fairly complete and should suffice for any modeling approach attempted for the Estero Bay Watershed. Some suggestions are provided for future wetland simulation capabilities.

7.3. PERLND Module Upgrades

The first recommendation is to complete the upland nutrient balance calculations. The original model was developed for applications dealing with agricultural operations. A plant uptake mechanism was included for both phosphorus and nitrogen but no corresponding dieback mechanism was included. This omission may have come about because mature crops are harvested and the nutrients are removed from the system. Simulation of natural systems which exhibit nutrient cycling over the course of a year requires the simulation of plant dieback and nutrient release back to the soil.

The model should include explicit capabilities for plant dieback and harvest through modification of PHOS and NITR. The existing HSPF agrichemical sections PHOS and NITR include a one-way

plant uptake mechanism for nutrients which are incorporated into plant biomass during the growing season. Due to the way the compartment is simulated, no storage limits exist and no means is available for those nutrients to become available later in the simulation. The existing algorithm is suitable for simulation of crops that are harvested, thus physically removing the nutrients from the system. In natural systems, uptake of nutrients occurs during the growing season and release of nutrients occurs as plants die back during winter. However, not all nutrient uptake is released directly during dieback. Nutrients are also relocated to the plant root mass at this time. Changes to the model to incorporate these mechanisms were found to be absolutely necessary to simulate the nutrient dynamics of wetland systems in particular. In addition, it was found that the existing algorithm based the amount of uptake on a first order rate applied to the amount of nutrient in solution. A correction to base the nutrient demand (satisfied if available in solution) on the plant biomass provided greatly improved simulation results. Capability should also be added to allow redistribution of nutrients to the various modeled soil layers resulting from changes in the plant standing crop and root mass throughout the growing season. Monthly tables specifying plant biomass for each soil layer are also needed to support this modification.

The calculation for the first-order nutrient uptake mechanism is presently based on the amount of nutrient (N or P) in solution. This phenomenon can be better simulated if the first-order rate is based on the biomass (standing crop) in each soil layer. The capability to specify the standing crop for each layer monthly should be provided.

Another recommendation is to add the capability for time series nutrient inputs to the upland module. The existing HSPF model does not include a mechanism for direct time series input of nutrients to the upland. Such a mechanism would accommodate atmospheric bulk precipitation and fertilizer inputs. Modeling experience has shown that this input should be directed toward the adsorbed soil compartments rather than solution compartments so that equilibrium is calculated first and the material is not simply exported from the watershed. This would allow easier simulation of events such as fertilizer application, nutrient inputs from the atmosphere (bulk precipitation) and would better support nutrient flow routing from one land module to another. A planned wetland module would presumably make use of most of the same modeling routines for nutrient simulation as the standard upland module and would similarly benefit from the nutrient flow routing capability. The existing model does have a cumbersome Special-Actions mechanism for modifying any variable at any time during the model execution, but this depends on identifying the correct variable address in memory and is not well-suited to accommodate a routine input time series. This mechanism is somewhat difficult to use but can be applied to occasional inputs such as fertilizer application. The overhead involved in additional input data preparation makes this mechanism unsuitable for continuous time series data such as bulk precipitation inputs.

Nutrient transport is allowed in the downward direction only through the soil layers. Plant nutrient storages are limited to one compartment. A useful upgrade would allow redistribution of nutrients in the various soil layers according to plant biomass distribution over the annual cycle.

Unidirectional downward flow results in leaching of quality constituents from upper soil layers. The model includes some retardation factors to control this unrealistic leaching, but this causes other problems. One reason this occurs is that there is no limit to the water storage capacity of the active groundwater layer. As a result downward flow always occurs resulting in excessive leaching. Providing a defined capacity for the active groundwater storage so that the inflow is appropriately limited at times solves this problem. It appears that the revised PERLND hydrologic routines function this way so that this water quality problem may be fixed. Model testing is needed to verify this problem is corrected; otherwise a means to limit the storage should be included.

Sediment removal from the watershed is often closely related to rainfall intensity and duration. A useful upgrade for the model would be to incorporate a means to consider intensity if the simulation time step is longer than 5 or 15 minutes. An intensity-duration factor could vary seasonally based on an analysis of existing meteorological data.

A number of HSPF input parameters may be varied on a monthly basis to reflect changing conditions over the annual cycle. Many of the monthly tables are used to interpolate values so that the parameter is varied smoothly. The ability to specify a start date for changes to take effect would be useful in some cases to more closely track changes in the watershed. In some instances a deliberate step change at a specific point in time would be more appropriate for some functions.

7.4. Wetland Systems

Wetland simulation with the existing HSPF model must be done with the RCHRES module. Available simulation mechanisms in RCHRES are insufficient for complete wetland water quality simulation. Water quality abilities similar to those available for uplands are needed to fully consider the interaction with wetland soils and vegetation.

A wetlands module to simulate wetlands hydrologic features is under development. Ideally, the quality algorithms available within the existing PERLND and RCHRES modules should be made available for use with a new wetlands module. If PERLND routines are used for the wetland simulation, solution phosphorus and nitrogen inflow mechanisms for the PERLND module nutrient routines are lacking. If RCHRES routines are used, interaction between water column and wetland soils is limited. Wetland vegetation cannot be directly considered within RCHRES.